The Bridging Work of Educational Informatics
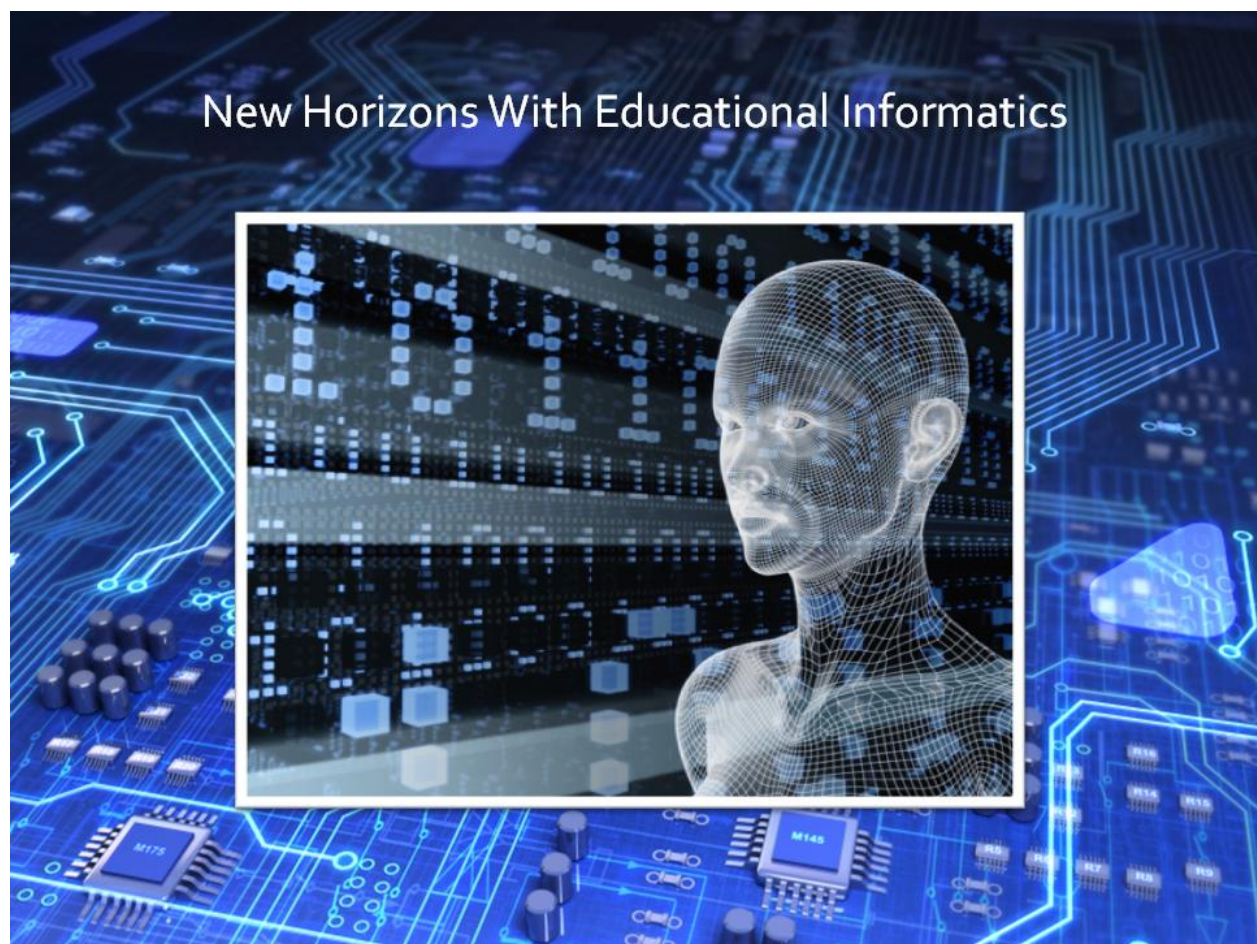
Supporting Innovations Across Virtual and Real-World Learning Environments

10/22/2009

Report Documentation Page		*Form Approved* *OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **22 OCT 2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**
4. TITLE AND SUBTITLE **The Bridging Work of Educational Informatics Supporting Innovations Across Virtual and Real-World Learning Environments**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Air University,Innovations & Integration,Maxwell AFB,AL,36112**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**12**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The Bridging Work of Educational Informatics Supporting Innovations
Across Virtual and Real-World Learning Environments

Andrew G. Stricker, Ph.D.
Air University

Toni Scribner
Air University

Abstract

The Air Force community will see growing interconnectivity between the physical world and virtual worlds to better support or augment and bridge formal and informal learning and decision support across a lifelong continuum of service. The seams between virtual and physical systems will increasingly become ubiquitous in service to lifelong learning and support of Airmen. For example, advances in informatics, the science and design of interactions between natural and artificial systems, will provide the means for Airmen to explore new ways of using knowledge within immersive synthetic environments and then transfer the insights into better performance in the real world that can be less forgiving when mistakes are made. We will also increasingly see virtual and physical education systems bridged in support of formal classroom learning, mobile learning on-the-job, and on-the-job decision support systems. For example, operational systems will increasingly be designed and deployed to offer dual-purpose roles for on-demand learning and decision support. Such dual-purpose systems will help shrink the gap between our schoolhouses and workplaces and further leverages our resources smartly for developing future Airmen.

Introduction: What is Educational Informatics?

Educational informatics melds the study of computer science with analysis of learning information and knowledge, to address the interface between computer, learning, and assessment sciences in the design of interactions between natural and artificial systems supporting learning, instruction, and discovery. Informatics, and related application areas such as educational informatics, is an interdisciplinary field (Scheessele, 2007). There are multiple supporting or component sciences behind educational informatics: decision sciences, cognitive science, information science, and even management sciences. As an interdisciplinary field, educational informatics, deals with information, data, and knowledge in the domain of education —their storage, retrieval, and optimal use for problem-solving and decision-making in support of how people learn, instruct, and discover new knowledge. In short, educational informatics turns data and information into knowledge that people can

use when learning, instructing, or discovering.

Beyond advances in learning science, the emergence of educational informatics as a new discipline is also due in large part to rapid advances in computing and communications technology, to an increasing awareness that the knowledge base of learning is essentially unmanageable by traditional methods, and to a growing conviction that the process of informed decision-making about learning is as important to modern learning environments as is the collection of digital learning resources, electronic curricular structures, and learning data on which design decisions or instructional plans are made. In general, educational informatics researchers can derive their inspiration from a number of application areas, identifying fundamental issues that need to be addressed and testing them in prototypes for more mature methods and tools, for future uses in learning environments.

The Work of Educational Informatics

The growing field of educational informatics offers applied research and prototyping effort to leverage advances in informatics to help interconnect natural and artificial education systems supporting learning, instruction, and discovery. The capabilities of new media and modern networks provide for services that can transcribe and integrate information between interfaces whether they are informational services (informal, broad public access) or business services (contractual, user access only). Such capabilities can help interconnect natural and artificial education systems, across live, virtual, and constructive (LVC) learning environments. In the case of LVC applications, improvements offered by educational informatics can help to better interconnect LVC learning environments for hybrid and mobile uses. For example, mobile learning devices can help bridge or provide for a continuum of learning services as the learner moves across LVC learning environments. With seamless connectivity learners could interact easily and intuitively between natural and artificial education systems. Interestingly, cloud computing (providing for on-demand configurable, scalable, shared computing resources through the Internet; many of which can be virtualized) offers architectures for the application of educational informatics to help secure and use data spanning across LVC learning environments.

The following basic functions are typically addressed within the work of educational informatics: data acquisition and presentation, record keeping and access, communication and integration of information, monitoring, information storage and retrieval, data analysis, decision

support, and education. Each function is briefly described below.[1]

Data Acquisition. Advance forms of educational technologies provide for vast collections of domain-related knowledge resources, learner history, learning assessments, knowledge performance data, and real-time data capturing. For example, adaptive precision learning systems rely upon data acquisition before and during the learning event to help build initial learner profiles or portfolios. Advanced data acquisition methods use computer-based learner-monitoring systems for collecting certain types of data just-in-time or directly during learning activity. Rapid advancements are being seen in the use of sensors for data acquisition from learning environments. For example, sensors placed in the environment can detect and record events, match location and time with information, and trigger retrieval and sending of information. Such capabilities can help bridge information associated with location, event, mobility, and research data to learning.

Record Keeping. A number of learner records can exist across formal and informal learning systems. Learning and performance data can exist in raw and tabulated form for producing reports.

[1] The basic functions and descriptions, adapted in this paper for application with educational informatics, are from practices in medical informatics, originally described by Wiederhold and Shortliffe (2001, pp. 182-186).

Many forms of data can also be used in support of multiple or aggregate reports involving input from interconnecting operating systems; for example, admissions, enrollment, course and learning management, registrar, audits, resource usage, etc. Informatics can help to connect disparate systems as well as reduce errors when information is integrated from multiple sources for record keeping. Educational informatics record filters can also help with providing users with higher levels of quality and trusted information originating from multiple sources. For example, filters can cross-check student records for trusted information on identity, transfer credit, degree requirements, enrollment and registration status, graduation requirements, degree audits, advisor recommendations, academic holds, etc.

Communication and Integration. A myriad of data can be collected on learners, at distributed locations, across a variety of learning settings. Communication among educators, with access to learning data, supports helping individual learners over longer spans of instruction or development as well as spotting trends among groups to improve instruction, manage learning plans, assess and remediate challenges, and interpret outcome measures for improvements. Access to integrated data, when and where needed, can be immensely helpful to decision makers. Also, administrators benefit from integrated

education outcome measures and financial information to analyze costs and evaluate the efficiency of education systems. Local-area networks that can support sharing of information among independent computers and wide-area networks supporting exchange of information among geographically distributed sites can also provide for enterprise-wide and global communication infrastructures in support of learning.

Monitoring. Data can indicate a need for action. For example, in the case of precision learning assessment (PLA), which integrates precision teaching and norm-referenced assessment techniques, normative standards can be used against which frequent comparisons of a learner's progress can be made to inform decisions for prescriptive instructional changes. Monitoring methods can call attention to targeted understanding levels or performance thresholds by correlating data from multiple sources. Also, similar to data acquisition, the use of sensors can support monitoring of learners across or within highly mobile learning environments. For example, learning paths and resources selected by users can be noninvasively monitored by sensors to better inform, mediate, and improve instruction. Another example is the use of sensors in immersive metaverses by virtual hospitals to monitor laboratory and clinic locations visited, paths taken to obtain information, choices and actions of medical students when learning

from scenarios involving the use of simulated medical equipment, procedures, making assessments and decisions for treatment protocols and receiving feedback on what produces the most desirable results.

Information Storage and Retrieval. Effective retrieval is very dependent on how well information is indexed for storage in support of the variety of user needs or use of the information. In many cases, the effectiveness of retrieval is dependent on how well the information is structured in relation to standard taxonomies and indexed to accurately convey context of user-centered creation, purpose, practicality for answering questions and solving common problems, and other metadata indices used by digital libraries and other knowledge management tools. For example, obtaining assessment data about a learner for prescriptive instruction or course planning purposes differs from the needs and context of registrars conducting degree audit checks or researchers conducting institutional outcome assessments. Data quality and validation are dependent not only on data acquisition methods and processes but also on how information is stored and retrieved. For example, noise-rejection or reduction algorithms employed by educational informatics can improve both quality and validity of information. Choices between continuous versus intermittent monitoring of learning activity and performance can

impact not only quality and validity, but costs associated with storage and retrieval of information.

Data Analysis. Computer collected data on learners can become enormous.   Data analysis systems can aid decision-makers by presenting information on learners, using rules engines based on informatics analysis tools and methods, to help identify trends, or spot potential problems in a sea of data. On a larger scale, data analysis can be applied to help analyze and interpret large sets of group data across the education enterprise (e.g., by courses, departments, colleges, universities, etc.).   Educational informatics can help with making data analysis methods more flexible and extensible to allow for micro and macro data details and views depending on role. For example, data analysis dashboards can provide for flexible and extensible data views on the basis of whether the user is a student, faculty member, department head, dean, or senior administrator.
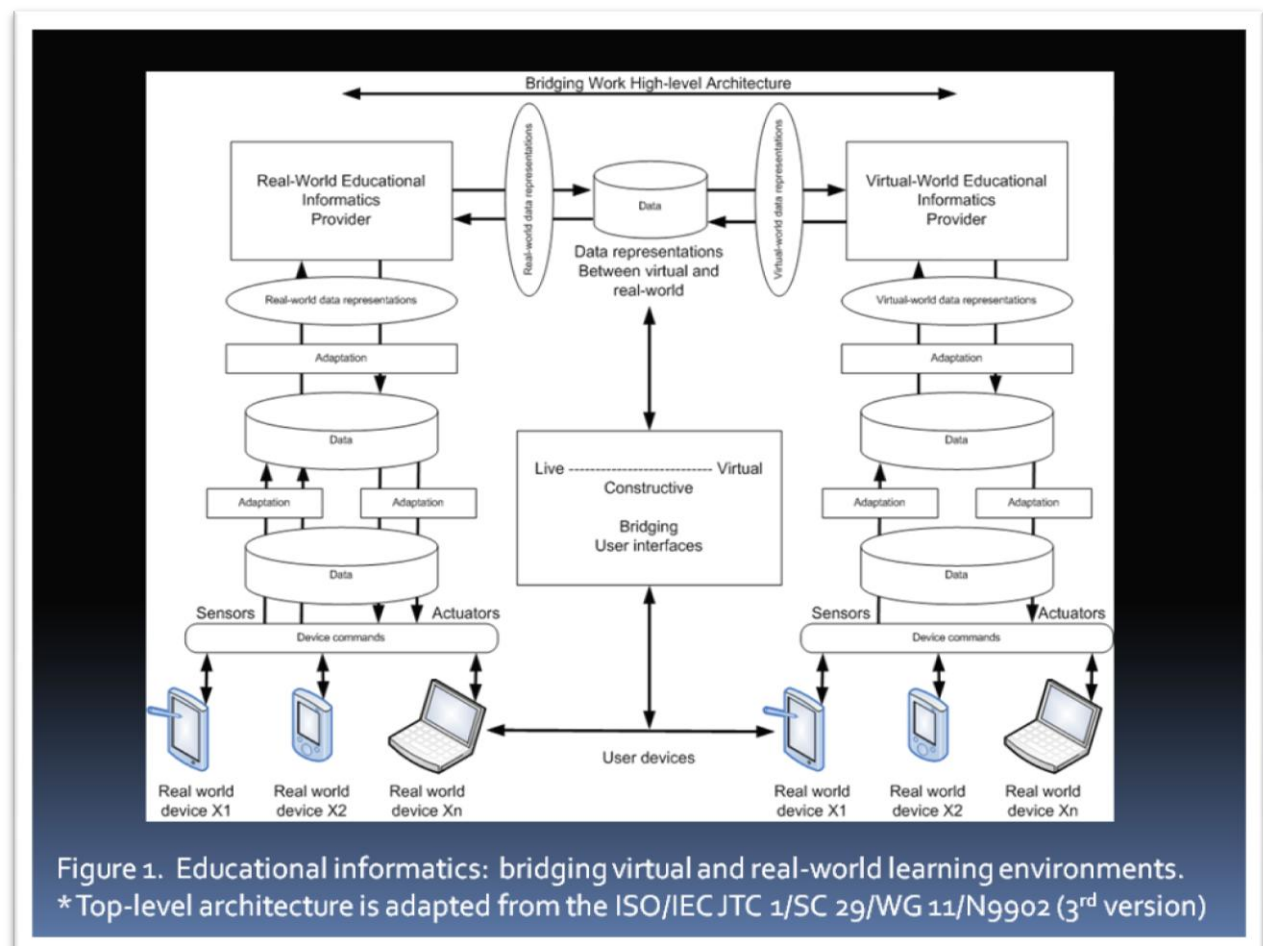
Decision Support.   On a higher level of visibility of educational informatics to users, decision-support systems offer greater assistance for focusing attention, providing interpretative assistance, and recommendations for specific action. Typically, algorithmic, statistical, or artificial intelligence techniques are employed by various levels of decision-support systems. On the high end, a decision-support system can offer an educator the use of population statistics or expert knowledge to assist with learner needs analysis, interpretative assistance with assessment data, prescriptive instruction suggestions and planning, or even help with locating and allocating learning resources. In particular, educational informatics offers the means to integrate data analysis services from one organization in support of decision support services offered by another. On the lower end, decision-support systems can offer means for individual, shared or team involvement with decision options, help weigh and sort multiple criteria, and make options and recommendations incrementally formalized and visible for further consideration and action. On both ends of decision support systems, the inclusion of visualization tools for interactive three-dimensional models can help users to better interpret complex data and develop shared understandings among team members of how best to address challenges with decision-action options.

Education.   Increasingly, due to rapid growth in knowledge, learners cannot learn all they need to learn during attendance or participation in formal education programs. Instead, learners must learn *how to learn* for lifelong development across formal and informal learning environments.   Also, limited resources can place additional time, availability, and access constraints on formal training and education programs. Fortunately, computer-aided instruction and new media social networking and

virtual world capabilities offer means to offset limited resources while also providing benefit from distributed electronic

by educational informatics, can offer interfaces which effectively integrate virtual simulation tools, three-dimensional

Figure 1. Educational informatics: bridging virtual and real-world learning environments.
*Top-level architecture is adapted from the ISO/IEC JTC 1/SC 29/WG 11/N9902 (3rd version)

availability, on-demand access, mobility, and applications from educational informatics. At this level of application, educational informatics enable the next generation of learning technologies operating across formal and informal learning programs and across virtual and real-world learning environments. A closer integration of information flowing between applications and systems across virtual and real-world learning environments offers multiple benefits for future learning. For instance, learning technologies, supported

instantiated models, data mashups using real-world datasets, in support of "what if" analysis behind model-based reasoning development. Also, in similar ways, educational informatics used in real-world systems can support virtual world learning environments to help enhance learners' ability to apply abstract knowledge by situating education in virtual contexts similar to environments in which learners' skills will be used (e.g., virtual hospitals for medical training (Alessandro, et. al., 2005), virtual Joint Air Operations Centers for

network centric warfare training and education, biodefense learning collaboratories (Alessandro, et. al., 2005), virtual pre-deployment training, etc.). Figure 1 depicts a high-level architecture of the bridging work of educational informatics across virtual and real-world learning environments.

From our observation, application of educational informatics functional areas ought to be closely aligned with the science and knowledge about how people learn. For example, the following principles about the nature of how people learn can inform thinking about the application of educational informatics:[2]

- Learners interpret every learning experience through an existing mental model (Bransford, Franks, Vye, & Sherwood, 1989; Cognition and Technology Group at Vanderbilt, 1990).
- Acquiring and retaining new concepts and skills can be strengthened when connected and integrated with existing knowledge if learning is active and constructive rather than passive and assimilative (Resnick, 1987).
- Learning is dependent on beliefs, attitudes, affect, and style of learning based on cognitive, sensory, psychomotor, and social

factors; tailoring instruction to individual styles can increase learning effectiveness (Cohen, 1987).
- Learning is enhanced by situating learning in an environment similar to that in which the knowledge will be used (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991).
- Learning is continuous and unbounded; people who treat every situation as an opportunity for growth learn more than those who limit their education to classroom settings (Dede & Fontana, 1995).

Application of the above principles on how people learn can be supported by educational informatics to better support or augment and bridge formal and informal learning environments and their representations in both the real world and virtual worlds. The bridging work of educational informatics can support connections and data flow between real-world and virtual education systems to provide means for using knowledge within immersive synthetic environments and then transfer insights and acquired skills into higher levels of performance in the real world that can be less forgiving when mistakes are made. Connections and data flow between virtual and real-world systems, enabled by educational informatics, also support stronger ties between formal classroom learning, mobile

---

[2] The list of learning principles is an adaptation from the list offered by Dede and Fontana (1995).

learning on-the-job and on-the-job decision support systems.

Prototyping Educational Informatics

Educational informatics can offer considerable benefits for supporting how people learn and help with integrating decision support and education services across an enterprise. Harvesting benefits from educational informatics does entail varying levels of system development effort coupled with organizational change management to address levels of change. Educational informatics design-build efforts can introduce mega or micro levels of change. Participatory design-build efforts, involving prototyping, provides means for the active role of users in the process while helping to reduce resistance and managing realistic expectations (Kautz, 1996). A prototype is a working model involving key features of the system under development. A collaborative design-build (CDB) approach, involving iterative prototyping, is increasingly used to engage designers, developers, and users in crafting and adapting future education systems (Stricker, et. al., 2009).

Crafting future education systems often introduces challenges with integrating a myriad of software and information services, many of which rely upon Web-based services using remote access to databases supporting distributed local applications. It is not uncommon for learning enterprises to consist of a variety of purchased, adapted, and in-house developed systems and subsystems that overlap with replicated data and have gaps in service levels for user groups. Also, making changes to education systems can introduce 2nd-and 3rd order change effects in the environment or learning ecosystem involving information flows, patterns of communication, perceived influence, authority, and control among users. Introducing new system capabilities also tends to increase tension for change to existing policies, business rules, governance, support resources, and methods of how work is done across learning, instruction, discovery, and administrative areas of the education system. Thus, the use of a CDB approach, involving iterative prototyping, can help to not only improve that essential features of the system under development are addressed, but also facilitate consideration and planning for anticipated 2nd and 3rd order change effects to education systems. Specifically, addressing 2nd and 3rd order change effects can introduce prospects for maximizing innovation efforts by introducing orders-of-magnitude improvements to workflows, efficiency levels, quality, and overall service levels not usually encountered through incremental improvements of system features.

A prototyping path of educational informatics builds from fundamental conceptualization of the art-of-the-possible

to evaluation. A suggested sequence for a prototyping path is offered below:[3]

- Formulation of models for the acquisition, representation, processing, display, and transmission of information or knowledge in support of learning, instruction, and discovery.
- Developing innovative educational technology-based system working examples, using these models, to deliver information and knowledge to users.
- Assessing and refining working examples for increased reliability and validity for functioning as intended in learning environments.
- Studying the effects of implemented systems on the reasoning and behavior of users, as well as on the organization and delivery of educational informatics services for improvements.

A key aspect for successfully navigating the above suggested path for introducing a new educational informatics capability is attention to the general organizational climate in which the prototype system must function (Kautz, 1996). As mentioned previously, prototyping of educational informatics can introduce micro or mega-levels of ecosystem change. Typically, modifications, enhancements,

improvements, and upgrades introduce micro-levels of change in the ecosystem. Whereas, a completely new system or a very significant revision of an existing system would introduce mega-levels of change and also likely alter the way work is done (Lorenzi & Riley, pp. 188-189). CDB prototyping provides an educational informatics project manager opportunity for continuous assessment and planning for assisting people and organizations to pass from an old way of doing things to a new way of doing things using change management strategies.

Conclusion

Overall, effective application of educational informatics, for supporting innovations across virtual and real-world learning environments, requires attention not only to technical features and capabilities, but importantly to how people learn and react to change and impact to the organization for how work is done. Informatics project managers need to expect, identify, and deal with resistance to change and involve users in the changes by the use of CDB prototyping and practical change management strategies (Lorenzi & Riley, pp. 179-180).

Disclaimer

The opinions and viewpoints expressed in this paper are solely those of the authors and do not reflect official policy or position of the US government or the Department of

---

[3] The suggested path is an adaptation of a proposed typology of the science in medical informatics offered by Friedman (1995).

Defense (DoD), the United States Air Force, or Air University.

References

Alessandro, D. M., & Alessandro, M. P. (2005). Initial experiences in developing a chronologically organized digital library for continuing education in biodefense. *D-Lib Magazine*, 11(4), pp. 1-13.

Alessandro, M. P., Alessandro, D. M., Bakalar, R. S., Ashley, D. E., & Hendrix, M. C. (2005). The virtual naval hospital: The digital library as knowledge management tool for nomadic patrons. *Journal of Medical Library Association*, 93(1), pp. 16-20.

Bransford, J.D., Franks, J. J., Vye, N. J., & Sherwood, R. D. (1989). New approaches to instruction: Because wisdom can't be told. In S. Vosniadou and A. Orton (Eds.), Similarity and Analogical Reasoning (pp. 111-145). New York: Cambridge University Press.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), pp. 32-42.

Cognition and Technology Group at Vanderbilt. (1990). Anchored instruction and its relationship to situated cognition. *Educational Researcher*, 19(3), pp. 2-10.

Cohen, D. K. (1987). Teaching practice: Plus ca change. In P. Jackson (Ed.), *Contributing to educational change: Perspectives on research and practice* (pp. 76-89). Berkeley, CA: McCutchan.

Dede, C., & Fontana, L. (1995). Transforming health education via new media. In *Health and The New Media: Technologies Transforming Personal and Public Health*, Linda M. Harris (Ed.), Mahwah, NJ: Erlbaum.

Friedman, C.P. (1995). Where's the science in medical informatics? *Journal of the American Medical Informatics Association*, 2(1), pp. 65-67.

Kautz, K. (1996). User participation and participatory design: Topics in computing education. *Human-Computer Interaction*, 11(3), pp. 267-281.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lorenzi, N. M., & Riley, R. T. (2003). Public health informatics and organizational change. In *Public Health Informatics and Information Systems*, P. O'Carroll, W. Yasnoff, M. Ward, L. Ripp, E. Martin (Eds.), New York, NY: Springer-Verlag.

Resnick, L. B. (1987). Learning in school and out. *Educational Researcher*, 16(9), pp. 13-20.

Scheessele, M. R. (2007). The two cultures: A zero-sum game? *Forum on Public Policy: A Journal of the Oxford Round Table*.

Stricker, A.G., McCrocklin, M., Calongne, C., & Holm, J. (2009). Mining innovation prospects at the virtual seams in Pasteur's Quadrant. Unpublished

manuscript. Air University, Maxwell-Gunter AFB, AL.

Wiederhold, G., & Shortliffe, E. H. (2001). System design and engineering. In *Medical Informatics: Computer Applications in Health Care and Biomedicine*, Edward H. Shortliffe and Leslie E. Perreault (Eds.), New York, NY: Springer.